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IEEE/ASME Transactions on Mechatronics, Vol 3, No 4, December 1998, pages 293-301

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(54) Abstract Title
Combined camera-loudspeaker for a mobile phone

(57) A combined camera and loudspeaker device, providing a small footprint of reduced bulk suitable for use in a mobile phone, has a lens 20 and/or lens mounting plate 21 acting as a sound generating surface of the loudspeaker. A stack 22 of benders 31, which may be piezoelectric in form, provides focussing actuation and loudspeaker drive. Also envisaged are a camera focussing mechanism employing a stack of recurve benders and, further and separately, a loudspeaker mechanism employing a stack of recurve benders.

Figure 3

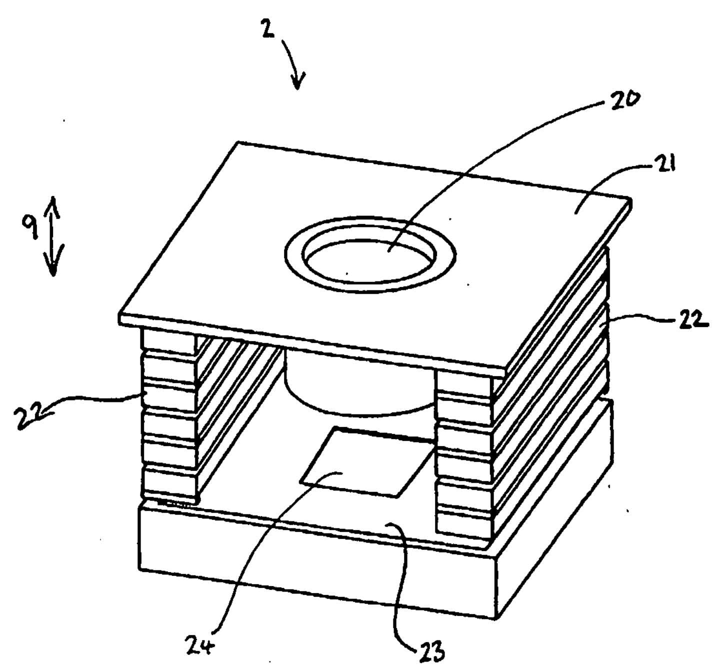

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Figure 1

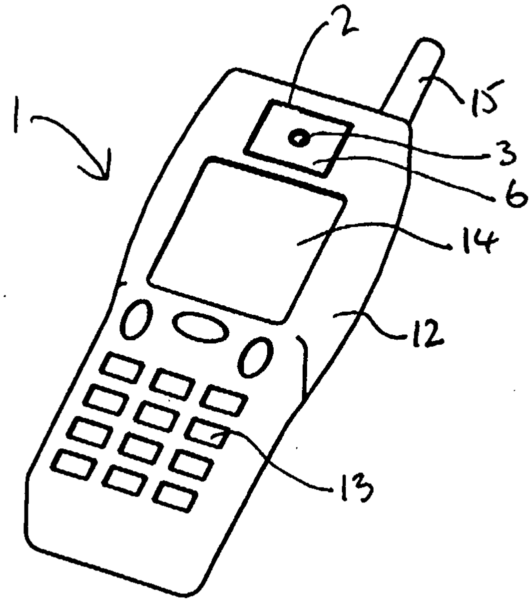


Figure 2

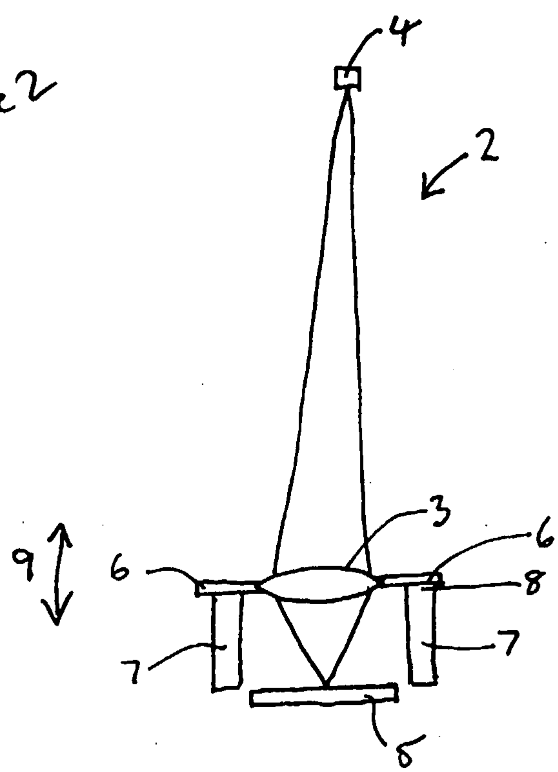


Figure 3

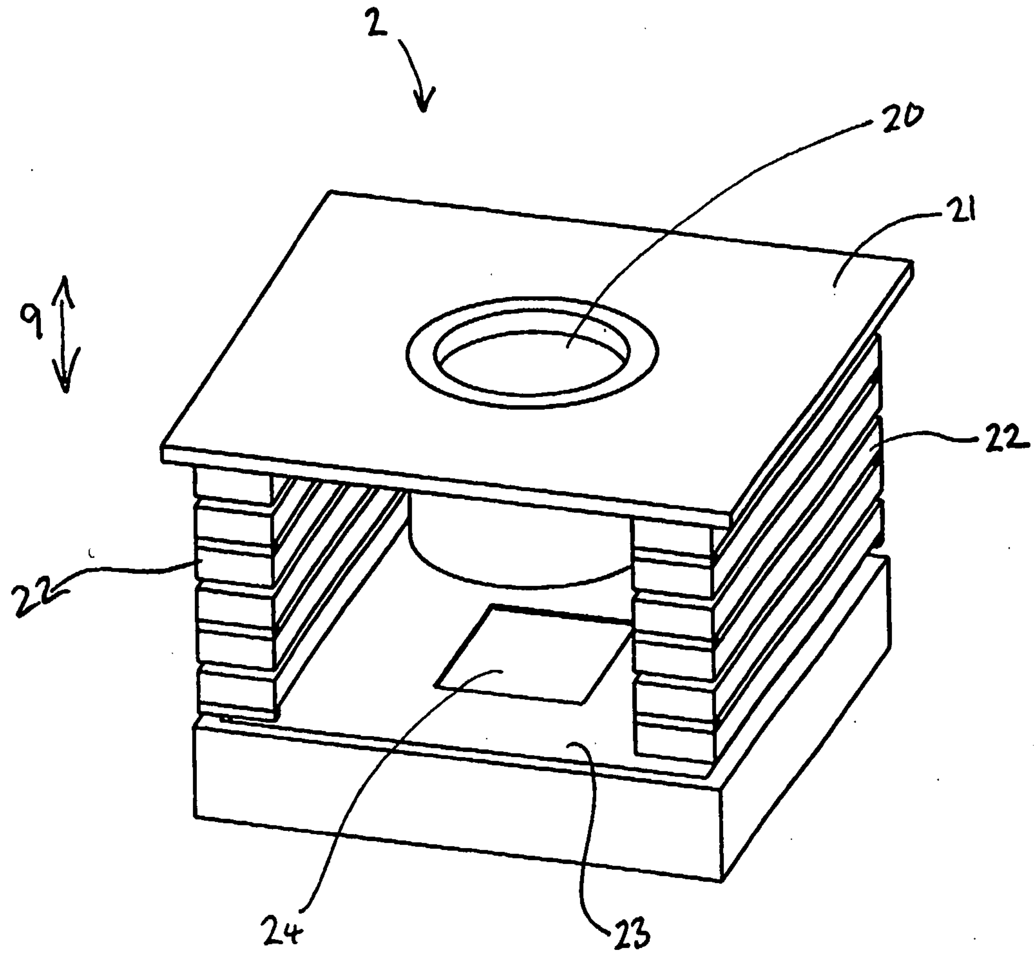


Figure 4a

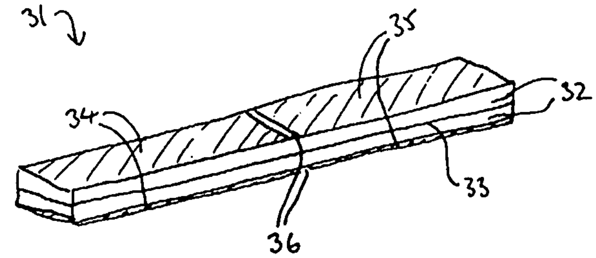


Figure 4b

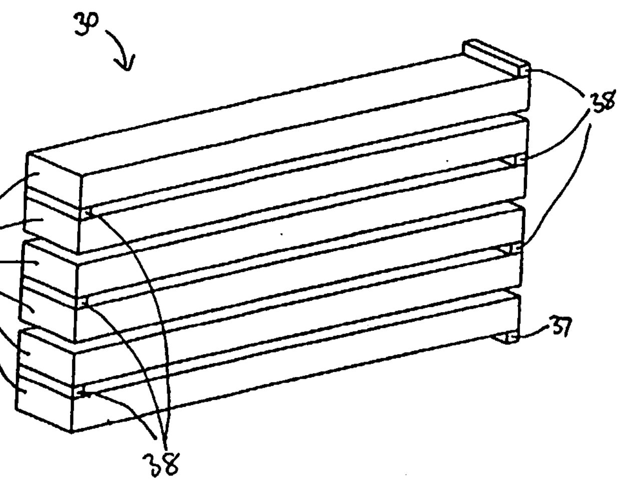


Figure 4c

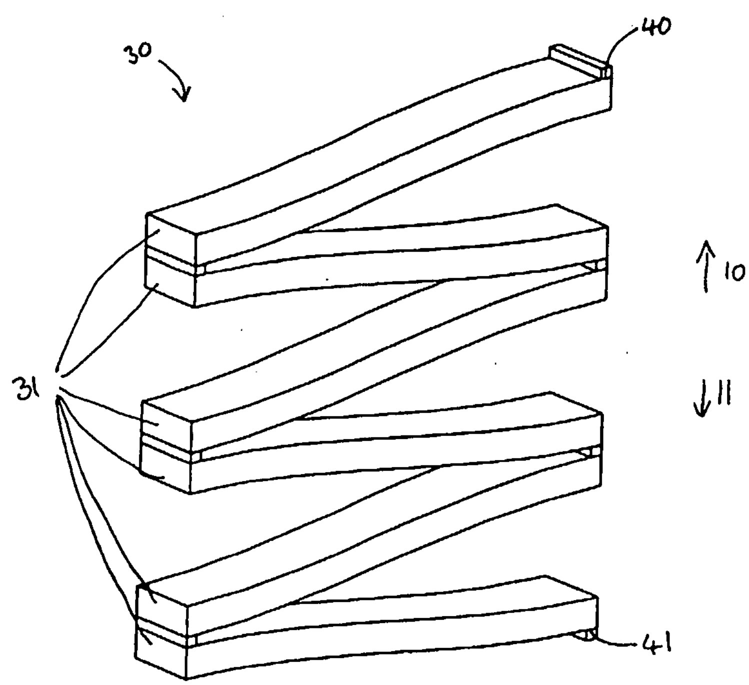
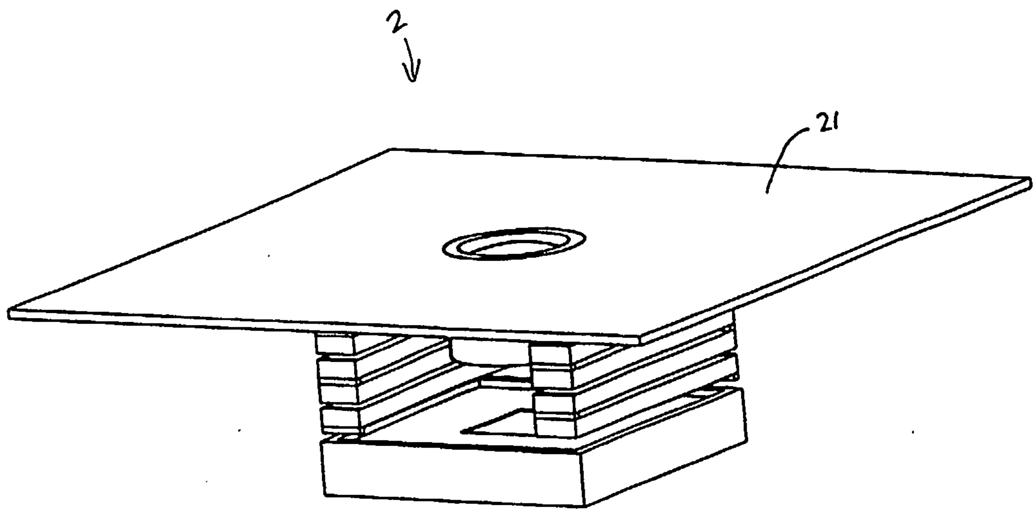


Figure 5



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IMPROVEMENTS IN OR RELATING TO MOBILE PHONES

The present invention relates to mobile phones, and concerns in particular loudspeakers and camera devices for use in these.

Conventional mobile phones which act simply as telephones are being increasingly replaced by multi-functional devices which provide additional functions such as internet access and image communication. At the same time, there is a drive to miniaturise mobile phone handsets.

A conventional mobile phone handset incorporates a small earpiece speaker allowing sound to be heard when held close to the ear. More recent mobile phones incorporate instead a loudspeaker which allows sound to be heard from a distance, for instance when the user holds the phone at arms length while viewing information on the mobile phone's screen. In order to produce more sound than the conventional earpiece, the loudspeaker has a larger diaphragm and a more powerful driver; it is therefore more bulky and massive than a conventional earpiece speaker. A further function which is increasingly being incorporated into mobile phones is a camera, which allows the user to take and send still and video images. The camera is a miniature digital camera, comprising a lens system and a digital image sensing device such as a CCD or CMOS light sensitive array chip. Whilst a fixed-focus camera can be used, variable focus, particularly automatic focus, provides greater functionality. Such cameras require an actuator to move the lens.

The phone loudspeaker and phone camera described above each typically has an area (footprint) of over a centimetre by a centimetre and a thickness of a few millimetres. Each requires an actuator, which is normally an electromagnetic motor, or voice coil. Such drivers comprise a magnetic core and a coil of wire; even at small scale such devices are relatively heavy, weighing a few grams. Thus, the incorporation of either loudspeaker or camera adds significantly to the bulk and mass of the mobile phone handset; the incorporation of both increases the bulk and mass yet more.

It is an object of the present invention to reduce the bulk and mass of multi-functional mobile phones by combining the loudspeaker and camera functions into a single component.

According to a first aspect of the present invention, therefore, there is provided a combined camera-loudspeaker for use in a mobile phone, in which the lens, or lens assembly, of the camera is also the diaphragm of the loudspeaker.

The advantage of this configuration is that the footprint of the combined camera-loudspeaker component is only about half that of the separate components, saving considerably on bulk.

The camera and loudspeaker each require an actuator. Although it is possible to use two actuators, one for the camera focussing function and one for the sound generation function, preferably a single actuator is used for both functions. This arrangement is in itself novel and inventive.

In a second aspect therefore, the invention provides a single electromechanical actuator that drives both the movement of the camera lens assembly, for focussing, and also the vibration of the lens assembly for generation of sound.

In this configuration, one actuator provides the functions both of focussing and of sound generation. Compared to two separate devices (one camera and one loudspeaker), the combined device has about half the mass, saving significantly on the mass of the mobile phone.

A lens assembly for use in a miniature digital camera, as manufactured for instance by Philips, generally has a relatively small area, of only a few millimetres squared. In its simplest embodiment, the device uses the camera lens assembly alone as the loudspeaker diaphragm. However, the relatively small area of effective diaphragm may not provide sufficient Sound Pressure Level (SPL) for a mobile phone loudspeaker. In a preferred embodiment, therefore, the lens assembly is carried in a mounting component of larger area so that the lens assembly and mounting together form the loudspeaker diaphragm. Indeed, the lens mounting can be designed specifically to provide the appropriate SPL.

In a further preferred embodiment of the invention, the mounting component is extended in area beyond the footprint of the device. Since this mounting component may be very thin, and is on the outward facing, or external, side of the device, it may extend in area without taking up valuable space inside the mobile phone.

In operation, the lens positioning is carried out fairly slowly, and infrequently. In contrast, the sound generation requires fast movement at frequencies typically in the range 100Hz to 5kHz. The excursion of the lens for focussing is typically up to 100 microns while the excursion for generation of sound is of the order of 10 microns to 100 microns (depending on frequency). Whilst vibration of the lens system might be thought to blur the image, in fact this is not the case. Indeed, high frequency vibration of a lens system through its focus point is a known method of increasing depth of field, since a camera chip (or indeed the eye) is able to select and retain the in-focus parts of the image in preference to blurred parts, producing an overall in-focus image. Thus, in operation the device of the invention is actuated such that the excursions to generate sound include the focal point of the lens.

In an alternative embodiment of the invention, the very low frequency movement of the lens for focussing is decoupled to a greater or lesser extent from the higher frequency sound vibrations. This is conveniently effected by a flexible coupling between the lens and its mounting. The actuator acts on the mounting and at very low frequencies the movement is transmitted through the flexible coupling to the lens, allowing focussing. At higher frequencies, the actuator vibrates the mounting, but the motion is not significantly transmitted through the flexible coupling to the lens. Thus, the lens vibrates hardly at all, and the sound is generated largely by vibration of the mounting. The flexible coupling may be designed as a vibration isolator specifically to provide whatever frequency transmission characteristics are required.

To provide an auto-focus function, the focus of the camera is controlled by feedback from the camera chip which, with its associated electronics and software, detects the position of optimum focus.

The actuator of the combined loudspeaker-camera may be any electromechanical device which generates movement in response to an electrical signal. For example, the actuator may be a known electrical motor or voice-coil. However, a preferred actuator of the invention is an electro-active or magneto-active device.

Electro-active devices are made from electro-active materials, which are materials which change shape in response to an electrical field. Examples of electro-active materials are piezoelectric materials, such as PZT (lead zirconate titante), and electrostrictive materials, such as PMNT. Magneto-active materials are materials which change shape in response to a magnetic field. An example is Terfenol. However, the actuators for the devices of the invention are preferably piezoelectric devices.

For operation to drive the lens both for focussing and as a loudspeaker, the actuator must be capable of generating motion of the order of 100 microns with a force sufficient to move the lens and its mounting and to accelerate them in an oscillatory way to produce sound. A block of piezoelectric material with dimensions of the order of millimetres moves a small fraction of a micron when activated. Even a similar-sized stack of piezoelectric blocks, or layers, provides only a micron or so of movement. These simple piezoelectric devices are therefore unsuitable for the actuator of the device of the invention. Piezoelectric materials in a bender construction, where two layers are coupled together, provide tip movements of several microns, due to bending caused by contraction of one layer while the other layer expands. Achievement of larger movements (of the order of tens of microns) requires a bender of very significant size, e.g. many centimetres in length. Such benders are inconveniently large, and are also rather compliant (that is, they cannot apply much force). In addition, the displacement of the tip of the bender on actuation is not linear in space; it follows a curve. Arrangement of a number of benders in a stack therefore produces a complicated and non-linear motion on activation. For several reasons, therefore, benders are not suitable for the actuator device of the invention.

In one preferred embodiment of the invention, the piezoelectric actuator is a stack of recurve benders, as described by J.D. Ervin and D. Brei in for instance IEEE/ASME Transactions on Mechatronics, Vol. 3, No. 4, December 1998, p293. In recurve benders, the bender is split into two parts along its length such that on activation one part curves in one direction while the other curves in the opposite direction. The combined effect is that the free end moves without rotation relative to the other, fixed, end, such that the ends remain parallel. The effectively linear displacement allows such benders to be stacked to provide additive movement perpendicular to the original plane of the benders. While these devices are known for use in, for instance, robotic grippers, wing reshaping and vibration control of helicoptor rotor blades, their use in either camera drivers or loudspeaker drivers is novel and inventive.

In third and fourth aspects of the invention, therefore, recurve bender stacks are used as actuators in camera focussing mechanisms and loudspeakers.

In a further preferred embodiment of the invention, the piezoelectric driver is instead of the type known as Helimorph^R, as described in our co-pending patent application Number PCT/GB00/04949.

Both CCD and CMOS imagers can incorporate an electronic shutter function, which allows the period over which incident light is integrated (the exposure time) to be reduced to as short as 60 microseconds. This is analogous to the mechanical shutter in a conventional camera, but is implemented simply by activating gates on the imaging chip.

To obtain a sharp image at a certain focal distance while the lens is oscillating, the exposure time can be reduced so that the shutter is only open as the lens passes through the correct focal position.

In low-light situations, the shorter exposure time may lead to a noisy image. If the imager can produce a higher frame rate than is required for the application, this can be overcome by summing the images produces each time the lens passes through the point of focus. This summing can be analogue, using the circuit elements on associated with each pixel on the imaging chip, or digital, using DSP to sum a number of digitised images.

For example, in a videoconferencing application, it may be desired to produce 16 video frames per second. If the lowest frequency which the speaker is to reproduce is 400Hz, then the audio signal will have a zero-crossing at least 800 times per second. If the audio drive signal to the lens/diaphragm assembly is offset such that the audio zero-crossings occur at the focal point, then there will be 800 in-focus moments per second, and hence 50 per frame. This will lead to a 17dB improvement in signal to noise ratio over the single-exposure case. If the audio zero-crossing point does not align with the in-focus point, higher audio output can be achieved whilst at extremes of focus, at the expense of fewer in-focus moments.

Furthermore, if the imager is capable of outputting frames at a high rate, then it can be useful to produce further images whilst away from the in-focus point. These can be used for feedback to the auto-focussing control system: if they are sharper than the supposed in-focus point, then it is likely that the subject has moved.

With a shallow depth-of-field (wide aperture) lens system, and significant computational power, the availability of a constant stream of images with different focusing points can allow three-dimensional scene analysis: areas of the image which show highest contrast/sharpness at a particular focusing distance correspond to objects at that distance. This "depth-map" information can allow more robust autofocus and flash-exposure decisions to be made, and can be helpful in object-based video coding, such as MPEG 4, in which the foreground and background are compressed separately to achieve higher efficiency.

The additional information resulting from producing images at different focal distances may make it worthwhile to use an audio signal to vibrate the lens/diaphragm assembly even when the loudspeaker is not being used for reproduction.

Embodiments of the invention are now described, though by way of illustration only, with reference to the accompanying drawings in which:

Figure 1 shows a mobile phone incorporating a camera/loudspeaker of the invention.

Figure 2 is a schematic cross-section through a camera/loudspeaker device.

Figure 3 shows a camera/loudspeaker in which the actuator is a pair of recurve bender stacks, suitable for use in the mobile phone of figure 1.

Figure 4 illustrates the construction and operation of the recurve bender stack.

Figure 5 shows a further camera/loudspeaker in which the sound radiating surface occupies a larger area than the underlying mechanism.

Figure 1 shows a mobile phone handset 1 incorporating a combined camera/loudspeaker device of the invention 2. The mobile phone handset 1 includes the usual features of case 12, touch sensitive key pad 13, screen 14 and aerial 15. In place of the conventional speaker, there is the combined loudspeaker/camera device of the invention 2, incorporating a lens 3 and mounting plate 6.

Figure 2 shows schematically a cross section through the combined camera-loudspeaker 2 of the invention. A lens 3 focusses light from a distant object 4 on to a CCD or CMOS chip 5 which lies in the image plane. The lens 3 is mounted in a mounting 6 which is coupled to an actuator 7. In response to an electrical signal, the top 8 of the actuator 7 moves up and down in the direction of the double headed arrow 9. The motion of the actuator 7 moves the lens 3 and its mounting 6 up and down. Positioning of the lens for optimum focus is achieved by feedback from the camera chip 5 which provides an appropriate electrical signal to the actuator 7. Similarly, electical signals representing sound are received by the actuator 7, causing vibration of the tip 8 of the actuator 7 in the direction of the double headed arrows 9. This vibration is transmitted to the lens 3 through its mounting 6, and this vibration of lens and mounting radiates sound, as in a conventional loudspeaker.

Figure 3 is a perspective drawing of a preferred embodiment of the invention in which the actuator is a pair of stacked recurve benders. The combined camera/loudspeaker 2 comprises a barrel shaped lens assembly 20 of the sort typically incorporated in miniature cameras and manufactured by for instance Philips. The lens assembly rests in and protrudes through a mounting plate 21, which in turn rests on a pair of stacked recurve benders 22. At the base of the device 2 is a CMOS chip 23 incorporating a light sensitive array 24, of the sort typically incorporated in miniature digital cameras and manufactured for instance by ST Microelectronics. The device 2 rests in a casing (not shown) which fixes the chip 23 and the base of the actuator 22, leaving the lens assembly 20 and mounting plate 21 free to move in the direction of the double headed arrow 9 when the actuator is activated.

Before describing the device 20 and its performance in more detail, the actuators will now be briefly described. Figure 4a shows a perspective view of a recurve bender 31 comprising two piezoelectric layers 32, a central electrode 33 and surface electrodes 34, 35 with a gap 36 between them half way along the length of the bender 31. Figure 4b shows a stack 22 of six recurve benders 31 (for clarity, the electrodes are not shown). In figure 3b, the lowest bender 31 is fixed to a base (not shown) at its right hand end 37 and joined to the bender above at its left hand end, by means of a spacer 38. This bender is in turn joined at its other end to the bender above and so on throughout the stack, the spacers 38 being at alternate ends. Figure 4c shows the stack 22 on activation, with all displacements grossly exaggerated for clarity. Each bender 31 curves in one sense at one end and in the opposite sense at the other end such that the ends of the benders remain parallel. The top of the stack is thereby displaced in the direction of the arrow 10 with respect to the bottom of the stack 41. Activation in the opposite sense causes the stack to contract instead, with the top of the stack displaced downwards in the direction of the arrow 11.

Returning to the camera/loudspeaker of figure 3, the actuator stacks 22 just described in figure 4 produce movement of the lens 20 and mounting plate 21 in the direction of the double headed arrow 9. The device of figure 3 is conveniently of small size for use in a mobile phone and a specific embodiment in terms of dimensions and performance will now be described. The device 2 measures 10.8x10.8 mm fitting in a case (not shown) with a footprint of 12x12 mm and a depth of 8 mm. The diameter of the lens barrel 20 is about 5 mm. The moving mass comprises the mass of the lens assembly 20 and the mounting plate 21 and is about 0.7 g. The recurve benders 31 measure 10 mm in length by 1.5 mm in width with a thickness of 0.6 mm, such that the stack 22 of six benders 31 and associated spacers 38 is about 6 mm in height. When made in hard PZT, such as grade 4D from Morgan Matroc, the stack produces a displacement on activation of about 100 microns. This is sufficient to provide focussing of the camera. At the same time, displacement in an oscillatory manner radiates sound from the top surface of the lens assembly 20 and mounting plate 21 with a Sound Pressure Level of about 72 dB.

Further improvements in sound radiation can be achieved in another preferred embodiment of the invention in which the mounting plate 21 extends beyond the footprint of the device 2, as illustrated in figure 5. In a specific example, while other dimensions remain the same, the area of the mounting plate 21 is now 24x24 mm. The moving mass is then 1.4 g and the Sound Pressure Level 80 dB.

CLAIMS

1. A combined camera-loudspeaker device for the use in a mobile phone, in which the lens, or lens assembly, of the camera forms at least part of the sound generating surface of the loudspeaker, such as a diaphragm.

2. A combined camera-loudspeaker device according to claim 1, comprising a single electromechanical actuator arranged to drive both movement of the camera lens assembly for focussing, and vibration of the lens assembly for generation of sound.

3. A combined camera-loudspeaker device according to claim 1 or 2, wherein the camera lens assembly alone forms the loudspeaker sound generating surface.

4. A combined camera-loudspeaker device according to claim 1 or 2, wherein the lens assembly is carried in a mounting component of larger area so that the lens assembly and mounting together form the loudspeaker sound generating surface.

5. A combined camera-loudspeaker device according to claim 4, wherein the mounting component extends in area beyond the footprint of the device.

6. A combined camera-loudspeaker device according to any one of the preceding claims, wherein the lens assembly is arranged to vibrate to generate sound around the point at which the lens assembly is in focus.

7. A combined camera-loudspeaker device according to claim 6, wherein the shutter is only open as the lens passes through the focal point.

8. A combined camera-loudspeaker device according to claim 7, wherein the images produced each time the lens passes through the focal point are summed.

9. A combined camera-loudspeaker device according to any one of claims 1 to 5, wherein the lens assembly is decoupled from sound vibration.

10. A combined camera-loudspeaker device according to claim 9, comprising a flexible coupling between the lens and its mounting.

11. A combined camera-loudspeaker device according to any one of the preceding claims, comprising an actuator which is an electro-active or magneto-active device.

12. A combined camera-loudspeaker device according to claim 9, wherein the actuator is a stack of recurve benders.

13. A camera-focussing mechanism employing a stack of recurve benders.

14. A loudspeaker mechanism employing a stack of recurve bends.

The Patent Office

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Application No: GB 0114655.4
Claims searched: 1 to 12

91

Examiner: Donal Grace
Date of search: 22 July 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H4F (FCCA) H4J (JA, JED, JK)

Int Cl (Ed.7): H04N 7/14, H04M 1/02 H04R 1/00, 7/00

Other: Online: WPI; EPODOC; JAPIO; INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	JP 080294030 A	(HITACHI) see figure 1 and WPI abstract accession number 1997-031926	1
A	US 5491507	(UMEZAWA et al)	1
A	IEEE/ASME Transactions on Mechatronics, Vol 3, No 4, December 1998, Ervin et al, "Recurve Piezoelectric-Strain-Amplifying Actuator Architecture", pages 293-301		

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
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